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ON

THE MORPHOLOGY OF RAVENELIA GLANDULÆFORMIS.

By G. H. PARKER.

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VIII.

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VI. — ON THE MORPHOLOGY OF RAVENELIA GLANDULÆFORMIS.

By G. H. Parker.

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At the suggestion of Dr. W. G. Farlow, in the fall of 1885, the writer commenced some investigations upon the leaf fungus known as *Ravenelia glandulæformis*, Berk. and Curt., and through the kindness of Mr. H. W. Ravenel an abundance of carefully selected material was placed at his disposal. This consisted of the dried leaves of the host plant, *Tephrosia virginiana*, Pers., which had been collected in 1879 at Aiken, S. C., by Mr. Ravenel, with the especial object of securing a series of the principal stages in the development of the fungus.

As may be seen from the literature of *Ravenelia*, our knowledge of this fungus is as yet incomplete, and questions of morphological interest concerning it are still unsettled. The object of this paper is to deal with one of these questions, namely, the morphology of the teleutosporic stage.

The young leaflets of *Tephrosia* show numerous dingy orange-colored spots scattered over both their upper and lower surfaces. These spots as a rule are more frequently met with below than above. On closer examination each spot is seen to consist of from one to several roundish or elongate swellings in the epidermis of the leaflet, the individual swellings often being ruptured above, and showing a cavity entering the tissue of the leaf. Usually, large clusters of such swellings on the lower surface of the leaflet are accompanied by several corresponding swellings on the upper surface, and almost invariably where swellings thus occur both above and below, the lower group is much the larger.

A transverse section of a leaflet in the region where the swellings

occur shows a cavity in the leaf tissue below each swelling. This cavity arises from a separation of the epidermis and the leaf parenchyma at their plane of union. The epidermis bows up, producing the appearance of the swellings previously described, and the leaf parenchyma, instead of following the epidermis in its upward folding, tears away from it, and remains unaltered in position, or by shrivelling slightly sinks downward away from the epidermis, and thus increases the intervening space. The cavity, since it has considerable lateral extension compared with its depth, is quite shallow. The leaf parenchyma forming its floor is penetrated in all directions by the mycelium of the fungus; this mycelium on approaching the lower surface of the cavity gives rise to a great number of upward-growing filaments, which project into the cavity itself and form a sort of hymenium. On the free ends of many of these filaments the yellowish uredospores are born. These spores, after ripening, generally escape through the crater-like opening in the epidermis above; but often before they have completely disappeared the dark brown glistening heads of the teleutosporic stage may be seen emerging from the lower surface of the cavity, and, in the older leaves, filling completely the crater-like openings, which soon become much larger by the crumbling away of the surrounding dried epidermis. Several of these openings, by continued increase in size, may eventually run together, and thus comparatively large spaces on the leaflet may be covered with teleutosporic heads.

Although the heads usually occupy old depressions made by the uredospores, they occasionally form depressions of their own. Such a group may be seen in Figure 1. Here several individuals are still under the epidermis, while one has burst through and is projecting from the upper surface of the leaflet. The under surface presents a broad depression, from which, unfortunately, most of the heads were removed in the process of softening and cutting. This lower cluster presented all the appearances of one developed in a depression previously formed by the uredospores, and it is probable that the heads above are simply an outgrowth from the same stock of mycelium as that which gave rise to the larger cluster below. Thus far, all the heads found on the leaflets have been easily referable to their respective depressions, the instance shown in Figure 1 being the most anomalous yet observed. Should the explanation as applied in this instance prove generally true, it may be stated that the heads on the leaflets develop at a later period, but in the same depressions as the uredospores.

The uredospores have been observed only on the leaflets; the heads, on the other hand, have been seen not only in this position, but also on the leaf rhachis and the young portions of the stem proper, in both of which positions the clusters are denser than on the leaflets. Whether the heads on the stem and rhachis do or do not originate in cavities previously occupied by the uredospores cannot here be definitely stated.

For the more careful study of the individual heads the following methods have been found of advantage. For thin sections, portions of the leaflet bearing the fungus were embedded in paraffine, and sections were cut with a Jung microtome as employed in animal histology. Material to be softened or cleared either for hand sections or teasing should be boiled in a strong solution of potassic hydrate until the brown color of the heads noticeably tinges the reagent. Fair results in maceration were attained when this process of boiling was continued beyond the point above mentioned; but care must be exercised lest the boiling should go so far as to discharge completely the color from the heads. In this condition the parts are too transparent, and their separation not so easily accomplished as at that stage where some color remains.

In outline, the head (Fig. 2) appears as a swollen, umbrella-like mass, rounded or flattened above and connected with the host by a moderate stalk. Three regions may be defined in it: first, the spore-mass or brown cap-like cluster of cells at the top; second, the cyst region, composed of cells with thin transparent walls connecting the spore-mass with the third or stalk region, consisting of a series of compressed parallel cells passing from the cysts to the leaf tissue below.

The spore-mass is a low dome of cells whose outlines by mutual pressure have become irregularly polygonal. The number of cells as viewed from above varies from two or three in extreme cases (Fig. 5), to as many as fifty, the average being perhaps thirty (Figs. 3 and 4). Externally these cells may be divided into two groups, the marginal cells or those on the periphery of the dome (Fig. 3 *a*), and the central cells, including all those which do not come to the edge (Fig. 3 *b*).

A cross-section of the spore-mass is a low arch of cells (Fig. 6) in which the marginal cell *a* is seen to occupy a position which in the central region is taken up by two cells, one external, *b*, and the other internal, *c*. This arrangement, although generally constant for most heads, nevertheless has its exceptions; for, in some instances, the position of a marginal cell is occupied by two cells bearing the same

relations to each other as the internal and external central cells, and again the place occupied by the internal and external central cells may be filled by a single cell. This latter case is comparatively rare, and where it has been observed the single cell was always next the marginal series.

By carefully treating the spore-mass with a hot solution of potassic hydrate, maceration was effected, and a pair of cells thus obtained is shown in Figure 7. The larger of these two is an external, the smaller an internal central cell; it is, however, as frequent an occurrence to find two internal or two external cells attached, as to find a group similar to that figured. The adhesion seems to be equally strong between all contiguous cells, and the grouping of incompletely macerated material is in consequence largely accidental.

The cells obtained by maceration lose their slightly angular outline, and become somewhat swollen. From the sections (Figs. 6 and 8), and from the isolated cells (Fig. 7), it will be seen that the outer walls of the external central cells, as well as the same walls of the marginal cells, are very much thickened, while those walls which are not exposed to the surface, but face contiguous cells, are thin. All the walls of the internal central cells are thin except those which are next the cyst region; these latter are of moderate thickness.

The line of separation between adjoining cells is usually discoverable without resort to reagents (Fig. 4); nevertheless difficulty may be experienced in separating two of the thin walls of adjacent cells. This difficulty can be overcome by checking the maceration process just before completion, when the lines of separation will have become well marked (Fig. 7). All the spore-cells contain a coarsely granular protoplasm, in the centre of which a nucleus may usually be discerned (Fig. 7).

The cyst region is composed of a number of rounded, transparent, thin-walled cells, forming a cluster somewhat smaller than the spore-mass itself, and connecting the latter with the stem region (Fig. 10). From the exterior it is difficult to make out the relationship existing between the cyst-cells and those of the spore-mass. In longitudinal sections, however, it may be seen (Fig. 8) that below each marginal cell and each pair of central cells there is a cyst-cell. This relationship seems to be almost invariable, — at least, in a long series of observations no exception has as yet occurred.

The individual cells in the centre of the cluster, from mutual pressure, are more or less angular. Those on the periphery have at least their outermost side convex, and often very decidedly so (Fig. 10).

The cell contents in the matured state seem to have disappeared completely, and all that remains is a delicate, thin-walled, almost transparent cyst, formed by the old cell wall. When the fungus has been allowed to ripen fully on the leaflet, the natural method for the detachment of the spore-mass seems to be by rupturing the cyst region. After the cysts have thus broken close to the stem, their jagged edges stand out as a sort of frill surrounding the spore-mass (Fig. 9). It is probably this stalkless stage of the American *R. glandulæformis* which has been considered identical with the Indian *R. sessilis*, Berk. When many spore-masses become thus disconnected with their stalks, the irregular margins of their frills may mat together and form a continuous layer. In one instance, a mat composed of perhaps a hundred such spore-masses was lifted on the point of a knife from the surface of the leaflet. It held its form well, and could be turned on a slide, so as to expose, first its upper, then its lower surface, without tearing the heads apart.

The stalk presents more difficulties in the way of its study than either of the other two regions. In the dried specimens it was so much shrivelled that all attempts to get good sections showing its relation to the cyst-cells failed. Moreover, the density of the embedding material was such that it intensified the shrivelling (Fig. 8). By maceration and surface study of specimens swollen in a warm solution of potassic hydrate fair results were obtained.

The stalk is undoubtedly compound, since by pressure it may be split into a number of longitudinal filaments, the stalk-cells, extending its whole length. From the exterior each of these cells may be seen to abut against a cyst-cell (Fig. 10), and, since but one stalk-cell has been seen to adhere to a cyst-cell in all successfully macerated material (Fig. 11), it is highly probable that each cyst-cell rests upon a stalk-cell in much the same way that the cells of the spore-mass rest upon those of the cyst region.

The cells of the stalk are long, and by mutual pressure more or less angular; at their tops they expand slightly in order to clasp the cyst-cells, and below they unite with the mycelium in the leaf tissue. They have walls as thin as those of the cyst-cells, but, unlike these, they appear to possess slightly granular contents.

Since each stalk-cell supports a cyst-cell, and this in its turn supports a spore-cell, it becomes possible to consider the whole head as composed of a bundle of fused aerial hyphæ, bearing spores on their summits. The hyphæ consist of two parts, a simple stem portion and a cyst-cell. Each hypha carries on its cyst-cell a spore, which, if the

hypha be marginal, is unilocular; if central, bilocular. If the morphology of the *Ravenelia* head be such as we have indicated, it is but natural to expect that confirmatory evidence should be found in its young stages.

The young heads first make their appearance amongst the paraphyses which line the cavities previously occupied by the uredospores. Portions of the leaflet on which these cavities were quite numerous were boiled in a weak solution of potassic hydrate, and picked to pieces with needles. Material thus teased contained the young heads, sometimes isolated, and sometimes attached to small fragments of leaf tissue.

The youngest head yet found (Fig. 12) consisted, in optical section, of four hyphæ, each of which is divided by cross partitions into three regions corresponding probably to the spore, the cyst-cell, and the stalk-cell of the matured head. Younger stages than this were difficult to distinguish from mere clusters of paraphyses, which are of not unfrequent occurrence. The individual paraphyses are generally smaller than a single hypha of such a specimen as that seen in Fig. 12, yet some of them attain a size much exceeding this, and intermediate clusters could probably be distinguished from very young heads only by the fact that their individual filaments would separate readily, whereas those of a true head are quite firmly bound together. It is probable that the hypha cluster destined to form a head rises from the mycelium at the base of the paraphyses, and from its first appearance is more or less consolidated. The stage seen in Fig. 12 is a slight advance on this condition. The head has begun to rise, and the hyphæ are elongating; the two primary sets of cross partitions have appeared, being the first intimations of the spore, cyst, and stalk regions. All the cells are filled with a granular protoplasm. A still more advanced stage is seen in Fig. 13. This head was almost completely isolated from the surrounding leaf tissue and mycelium, and consequently shows more of the stalk region than is seen in Fig. 12. The spore-mass has become proportionally larger than in the earlier stage, and a plane of separation dividing its central cells into an external and an internal series has been developed; the increasing thickness of the walls of the spore-cells is noticeable, but no brown color has as yet appeared. The cells destined to become the cyst-cells are still unmodified. The stalk-cells are slightly elongated. Below these last, and similar to them in appearance, is another set of cells, of which no trace has been found in the matured head. In the later stages these doubtless serve as a basement structure, usually hidden

from view by the surrounding tissue. At this stage all the cells are filled with a finely granular protoplasm, and it is not until later that the cyst-cells lose their contents.

The further development of the head consists in an increase in the size of the spore-mass, accompanied with an enlargement of the cyst-cells and an elongation of the stem (Fig. 14). As the spore-mass develops, the outer walls of its cells continue to thicken, and at maturity assume a rich chestnut-brown color. The cyst-cells expand, and finally lose their contents. The stem, usually at quite a late period, becomes considerably lengthened, and the head, assuming the matured form, is lifted above the surface of the leaf.

In the course of the development of the head no feature has presented itself which cannot be easily harmonized with the proposition that the head is a bundle of fused hyphæ, bearing spores. In fact, since the earlier stages show the filamentous nature of the head more plainly than the more advanced conditions, and since a study of these stages explains how that arrangement is disguised in the mature head, it is evident that the course of development not only does not oppose our former hypothesis, but doubles the argument in favor of it. As a final statement concerning the morphological nature of the head, we may therefore assert, that, from the anatomy of both the matured and developing head, the structure is essentially that of a cluster of fused teleutosporic stalks, individually equivalent to a stalk and teleutospore of such a form as *Puccinia*, and collectively equal to a cluster of the same.

Having reached the above conclusion concerning the morphology of the teleutosporic stage of *Ravenelia glandulæformis*, it remains only for us to conclude with some notes upon a few of the other species of this genus. As preliminary to these, a short historical review of what is already known of these species may not be inappropriate.

With the exception of a recent paper by Mr. M. C. Cooke, the contributions to the literature of *Ravenelia* have been rather of a systematic nature than otherwise, and, although more or less anatomical detail is necessary in such work, still it must be remembered that anatomy was not the end sought for, but rather a necessary accompaniment.

The Rev. M. J. Berkeley first called attention to the genus *Ravenelia*, and in a short paper* gave descriptions of two species, *R. Indica*, Berk., and *R. glandulosa*, Berk. and Curt. The following

* The Gardeners' Chronicle, p. 132, 1853.

is a summary of the author's remarks on the anatomy of these species. *R. Indica* occurs on the pods of an Indian species of *Acacia;* the clusters of heads upon one side of the pod are represented by corresponding clusters on the opposite side. Upon careful examination, the head of *R. Indica* is seen to "consist of a large, umbrella-shaped dark cap," the spore-mass, "often $\frac{1}{250}$ of an inch across, composed of a number of closely packed cells, supported by a long, hyaline, delicate, and apparently compound stem, round the top of which is suspended a circle of elongate hyaline bodies," the cyst-cells. In *R. glandulosa*, the South Carolinian species, the stem is shorter than in *R. Indica*, and the hyaline bodies at the top of the stem are fused firmly together into a single mass, the cyst region. Two figures of each species accompany the text, and serve to illustrate the remarks already noted.

In his "Introduction to Cryptogamic Botany," p. 323, 1857, the Rev. Mr. Berkeley places *Ravenelia* in the *Cœomacei*, and states that "the spore," i. e. spore-mass, "is in this case of considerable size, and evidently reticulate, and below it, either free or in contact with the stem, is a circle of colorless bags, foreshadowing a more complicated system of articulation than even in the following group," *Pucciniæi*. On page 305 are two figures, one of *R. Indica* and the other of *R. glandulæformis*, Berk. and Curt. (= the former *R. glandulosa*, Berk. and Curt.), both essentially like those of the previous paper.

In 1873, Messrs. Berkeley and Broome presented to the Linnean Society for publication the second part of their "Enumeration of the Fungi of Ceylon," * and on page 93 of their paper five species of *Ravenelia* are described. The term pseudospore is here made to replace that of spore, as applied to the spore-mass. *R. Indica* is redescribed, and its cyst-cells are figured as having filiform processes extending from their centres back into the depths of the head. These are called "glandular stipitate bodies." *R. sessilis*, Berk., and *R. aculeifera*, Berk., are described as new. *R. macrocystis*, Berk. and Br., and *R. stictica*, Berk. and Br., also new species, are figured with a frill of mycelium-like threads, replacing in position the irregular line of the ruptured cyst-cells at the base of *R. sessilis*. The outer surface of the spore-mass of *R. stictica* is figured and described as slightly echinate.

The latest paper touching upon *Ravenelia* is that by Mr. M. C. Cooke.† In it all the species of the genus are described, with this

* Journ. Linn. Soc. (Bot.), XIV. pp. 29–140. 1875.

† The Genus Ravenelia. Journ. Roy. Micr. Soc., Ser. 1, Vol. III. Part 1, pp. 384 to 389. 1880.

change in the nomenclature, that the term capitule is substituted for pseudospore as employed by the Rev. Mr. Berkeley, and that this latter term is now used to designate the single spores of the spore-mass. *R. glandulæformis*, Berk. and Curt., and *R. Indica*, Berk., are redescribed. The remaining species are all sessile, and the author remarks, that, although they are "described as sessile, this must rather be interpreted to intimate that the stem is reduced to such a minimum as to be little more than a mere point of attachment." *R. glabra*, K. and Cke., is added. This last species, from the material at hand, seemed to have no stem- or cyst-cells, but Mr. Cooke is of the opinion that in fresh material the cyst-cells would probably be found. *R. aculeifera*, Berk., is spoken of as having hyaline processes at the base of its spore-mass, and shows no trace of either stem- or cyst-cells. *R. Hobsoni*, Cke. (= *R. stictica*, Berk. and Br., Grevillea, V. p. 15), has hyaline spines on its marginal spore-cells. *R. stictica*, Berk. and Br., is described as possessing small cysts and a spore-mass, with a warty outer surface. *R. macrocystis* has not been seen by the author.

The material available for anatomical work seems to have been largely *R. aculeifera*, Berk. By gentle pressure a spore-mass of this species can be broken up into its individual spore-cells, which are club-shaped, with their thick outer ends deep brown, and their narrower inner ends colorless. In all cases the single spores extend from the under to the upper surface of the spore-mass, and there is nothing in the central region corresponding to what we have described in *R. glandulæformis* as an internal and an external set of spore-cells; in other words, all the hyphæ of *R. aculeifera*, if there be such, bear unilocular spores. Other species were examined, and the author became convinced that the structure of the spore-mass was essentially the same in all, — a cluster of spores temporarily held together, but destined to separate at maturity. "The barren cysts which surround the capitules in some species yet require to be investigated. The stalk, in both *R. Indica* and *R. glandulæformis*, under pressure separates into parallel tubes. Probably, but this is only speculation, the number of threads may equal that of the pseudospores in the capitule."

The type of structure which we have suggested for *R. glandulæformis* is partially anticipated in Mr. Cooke's closing remark. To what extent this type explains the structure of the remaining species of *Ravenelia* is a question only to be answered after a careful comparative study. Through the kindness of Dr. Farlow, the writer was given access to the specimens of *Ravenelia* contained in the Curtis

collection, Dr. Farlow's private collection, and the exsiccati of various authors. The specimens from these three sources form the basis for the following notes.

The Curtis collection contained one specimen of *R. Indica*, Berk. In this specimen the fungus occurred as a large patch of heads on one side of an acacia pod. The single heads, when removed from the host and softened in a solution of potassic hydrate, appeared as in Figure 17. They consisted of a dark brown spore-mass subtended by cyst-cells, which, after being treated with potash, swelled, and hung from the lower edge of the spore-mass like a series of inflated bags. The stalk, although treated in the same manner as that of *R. glandulæformis*, showed nothing indicative of a compound nature. It appeared, moreover, to be attached at a central point on the lower face of the spore-mass, and was apparently not connected with the cyst-cells. Of all the species which we have examined, *R. Indica* has the longest stem, its length often being two or three times the breadth of the head.

The specimen referred to above was the only authenticated one representing this species in the collection. Besides this, however, there was some material from Mexico, which in its general habit was similar to that of *R. Indica* except that it occurred on the leaflets, and not the pods, of *Acacia*. Upon microscopic examination, the heads of the Indian (Fig. 17) and the Mexican form (Fig. 19) proved so like each other that they were practically indistinguishable. Since the only difference between these two forms was in their position on the host, we feel confident that the *Ravenelia* before us is no other than *R. Indica*. This species, we believe, has never before been found in America, and we take pleasure in announcing its discovery by Mr. C. G. Pringle, who collected it on *Acacia anisophylla*, Watson, and *A. crassifolia*, Gray, at Jimulco, Mexico.

In the Mexican specimens the heads occurred in dense dark brown patches on the upper surface of the leaflets of the two species of *Acacia* before mentioned. The patches are so large that they at times cover the leaflets on which they are situated. Single heads or small groups of heads may be found on both surfaces of the leaflet, but especially on the under side, directly below each large patch. The heads occur also here and there on the leaf rhachis.

A transverse section of a leaflet in the region of one of these patches shows the leaf tissue permeated in all directions by a firm-walled mycelium, which, under the patch, passes outward between the epidermal cells of the leaflet, and gives rise to a hymenium on the outer surface of the leaflet, whence arise the teleutosporic heads.

The epidermal layer is not ruptured and curled back as in *R. glandulæformis* (Fig. 1), but the individual cells retain their original positions, and the mycelium makes its way outward between them, curling up and reflecting only the heavy cuticula.

The hymenium consists of short paraphyses, which are closely packed together, each paraphysis having two or three transverse partitions. The young heads appear on a level with the summits of the paraphyses, and seem to be connected with the deeper mycelium by several stalk-cells. The older heads rise far above the paraphyses, and are supported by what appears to be one of the stalk-cells very greatly elongated. What has happened to the other stalk-cells, or whether the head was ever connected with more than one of these cells, is uncertain.

The matured head in cross-section (Fig. 18) shows a structure quite different from that of *R. glandulæformis*. The spores are throughout unilocular, and, although in the centre of the head each one is subtended by a cyst-cell, on the sides one large cyst-cell underlies two or even three of the spore-cells. The stalk is attached to one or two of these small central cyst-cells, and upon the application of a solution of potassic hydrate the larger lateral cysts swell into the balloon-like form seen in Figs. 17 and 19, and so hide the stalk that it appears to attach itself to the spore-mass independently of any cysts. The stalk, which becomes greatly elongated as the head matures, seems to be simple, and not compound as in *R. glandulæformis*.

Of all the species which we have examined, *R. Indica* is the only one in which the spore-cells are persistently unilocular, the stalk simple, and two or three spores often subtended by one cyst-cell. Unfortunately, *R. aculeifera* has not been examined; but, according to Mr. Cooke, this species also has unilocular spores, and it is therefore probable that *R. aculeifera* is of the same type of structure as *R. Indica*. These two species may then be placed in a group contrasted in the three characters already mentioned with *R. glandulæformis* and its allies.

Amongst the species closely related to *R. glandulæformis* is *R. glabra*, K. and Cke. This species was distributed in the Rabenhorst-Winter, Fungi Europæi, Nos. 2624 and 2624 b, upon the leaflets and leaf rhachis of *Calpurnia silvatica*, E. Mey. The teleutosporic heads occur in clusters scattered over the leaflets. These clusters are individually quite small compared with those of *R. glandulæformis*, and, unlike the latter, they are never placed so closely together as to give the appearance of covering the general surface of the leaflet. Each

cluster protrudes from a crater-like opening, which was formed by rupturing and reflecting the epidermis in much the same manner as in *R. glandulæformis.* The individual heads agree with those of the latter species in having practically the same structure; the spore-mass in longitudinal section (Fig. 20) shows the lateral and internal and external central cells arranged upon the same plan as in *R. glandulæformis;* one cyst-cell underlies each spore-cell in the base of the spore-mass; the stalk is compound, and the relation of its cells to the cysts is the same as in *R. glandulæformis.* What has already been said of the morphology of the American species will doubtless apply with equal force to *R. glabra.*

A third form which will come under the present group is a species which was described by the Rev. Mr. Berkeley as *R. sessilis*, and which was found upon *Acacia Lebbek* in Ceylon. The Curtis collection contained one specimen of this species, from which the head (Fig. 15) was taken. This specimen, together with others, was carefully studied, and, aside from the difference in the host and locality, no distinguishing mark could be found between it and *R. glandulæformis.* The spore-mass, cysts, and compound stalk agreed in detail with those of the American species, and we were unable by any structural peculiarity to distinguish them.

In addition to the Ceylon material, Ravenel's "Fungi Americani Exsiccati" contained a specimen labelled, "*Ravenelia sessilis*, Berk., *in foliis Tephrosiæ*, Aiken, S. C.," and it was through this specimen that *R. sessilis* had been attributed to America. Figure 16 represents a head from the Ravenel Exsiccati, and here, as in the previous case, a diligent search failed to bring to light any character distinguishing this from *R. glandulæformis.* Neither the host nor the locality in this case could serve to separate them, and consequently we can see no reason for considering them distinct.

It is then hardly open to doubt, that *R. sessilis* as distributed by Mr. Ravenel is *R. glandulæformis*, in which perhaps a majority of the ripened heads have broken from the stalks, as has already been explained, and appear on the leaflet in this stalkless condition. As we have before remarked, the Ceylon *R. sessilis* can only be distinguished from *R. glandulæformis* by the difference of its host and habitat, and not by any structural peculiarity. What the specific value of these characters is we leave to those better able to judge; for ourselves, we must candidly admit that, even in the case of the Ceylon *R. sessilis*, we do not see reasons enough for considering it distinct from *R. glandulæformis.*

The remaining two species differ from all those which we have mentioned in the finely tuberculate outer surface of their spore-masses. No. 10 of Vize's "Micro Fungi Exotici" is an East Indian *Ravenelia*, which, unlike all others, occurs not in clusters, but superficially scattered over the leaf of an unknown host. It is named *R. stictica*, Berk. and Br., and has a small head composed of half a dozen spore-cells, with cysts and a compound stem. Its stem and cyst-cells are arranged after the type of *R. glandulæformis*, but the spore-cells are all unilocular (Fig. 21), and in this respect it approaches *R. Indica*. However, since the spores appear to be subtended each by a cyst-cell, and these in turn supported by stalk-cells, its affinities as a whole are closer to *R. glandulæformis* than to *R. Indica*. The ornamentation of its spores is very characteristic; their whole outer surface is covered with small, wart-like protuberances, while on the periphery of the spore-mass these are so much elongated and enlarged that they appear as so many spines.

The second species agrees with the one just described in having the whole outer surface of its spore-mass covered with small prominences, but the heads are much larger and heavier than those of the former, and consist of about thirty closely compacted small spores, the lateral ones devoid of spines. This species was from Winter's Herbarium, and was labelled "*Ravenelia Tephrosiæ*, Kalchbr. On *Tephrosia* (*macropoda?*), Natal." The stalk is compound, and the cyst-cells, as far as can be seen externally, are arranged in accordance with the type of *R. glandulæformis*. The general habit of the fungus when seen on its host is strikingly like that of the last-named species.

With this we conclude the list of species which have come under our observation, and as a result of these notes we may present in closing two generalizations: first, that the species examined seem to fall under two distinct types of structure, one represented by *R. Indica*, and including that species and probably *R. aculeifera*, and the other represented by *R. glandulæformis*, and including *R. sessilis*, *R. glabra*, *R. Tephrosiæ*, and probably *R. stictica* (Vize); second, that all the species thus far examined have had well-developed stalks and cyst-cells, and that consequently the so-called sessile species are in all probability species in which the specimens studied were so ripe as to have ruptured their cyst-cells, and thus appeared stemless. Such species as are related to *R. glandulæformis* will probably be found to have much the same development as that form; those of the type of *R. Indica* require yet to be investigated, and we feel that it is in this direction that a profitable field for research awaits the future student of *Ravenelia*.

EXPLANATION OF FIGURES.

[All magnified 330 diameters.]

PLATE I.

Ravenelia glandulæformis, Berk. and Curt.

Fig. 1. A transverse section of the leaflet of *Tephrosia virginiana*, Pers. The normal condition of the leaf tissue is seen at the left. The section was cut with a hand razor after the leaflet had been softened in a warm solution of potassic hydrate.

Fig. 2. A head cut from the leaflet and mounted in alcohol to show the general habit.

Fig. 3. A spore-mass mounted in glycerine jelly, seen from above; *a*, marginal cells; *b*, central cells.

Fig. 4. A spore-mass mounted in alcohol, seen from above.

Fig. 5. An abnormal head mounted in alcohol, seen from the side. The cells *a*, *b*, and *c* have thick brown walls. The stalk is broken off.

Fig. 6. The cross-section of a spore-mass which has been treated with potassic hydrate and mounted in balsam. Lateral cell, *a*; external central cell, *b*; internal central cell, *c*.

Fig. 7. An internal and an external central cell from a head macerated in a solution of potassic hydrate.

Fig. 8. A transverse section of a head treated with alcohol, and mounted in balsam.

Fig. 9. A very ripe head mounted in alcohol and viewed from above. The spore-mass has broken from the stalk, and the ruptured cysts project beyond its periphery.

PLATE II.

Ravenelia glandulæformis, B. and C.

Fig. 10. A side view of a head treated with a warm solution of potassic hydrate.

Fig. 11. A head partially macerated in a warm solution of potassic hydrate, seen from the side.

Fig. 12. An optical section of a very young head, isolated by teasing a piece of leaf-tissue previously boiled in a solution of potassic hydrate.

Fig. 13. A head in a more advanced stage than the last, obtained by teasing.

Fig. 14. A side view of a still older head.

Ravenelia sessilis, Berk.

Fig. 15. A head treated with potassic hydrate. (Curtis Coll.)

Fig. 16. A head similarly treated. (Ravenel's Exsiccati.)

Ravenelia Indica, Berk.

Fig. 17. Side view of a head softened in potassic hydrate. (Curtis Coll.)

Fig. 18. A cross-section of a spore-mass mounted in balsam. (Mexico.)

Fig. 19. Side view of a head softened in a solution of potassic hydrate. (Mexico.)

FIG. 2

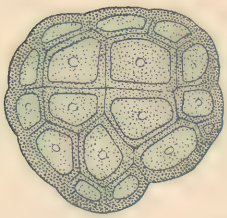

FIG. 4

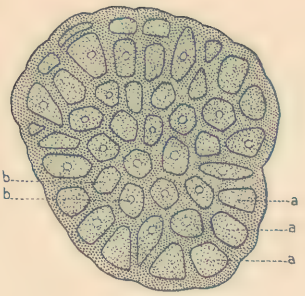

FIG. 3

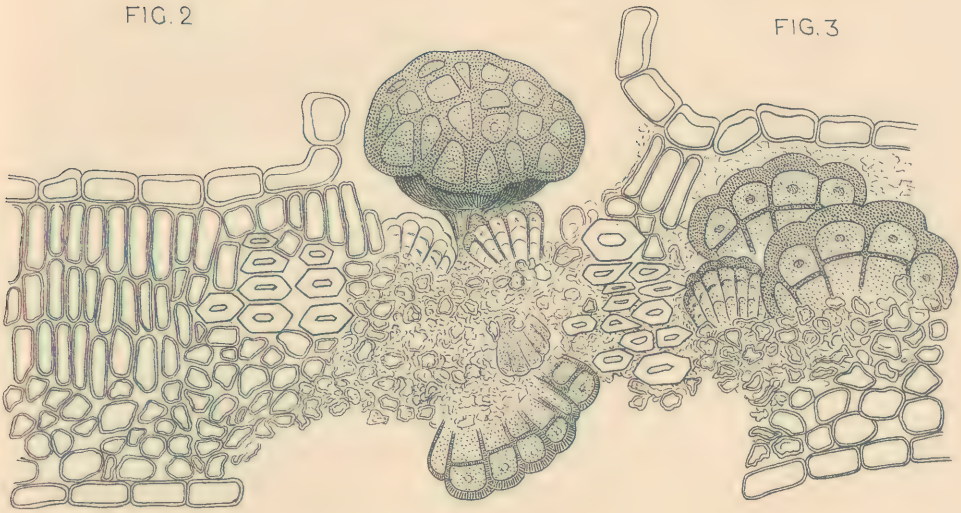

FIG. 1

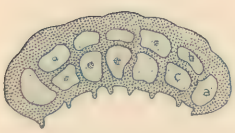

FIG. 6

FIG. 5

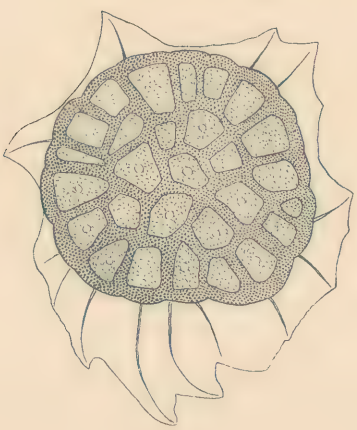

FIG. 9

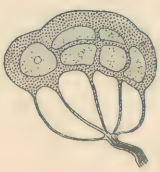

FIG. 8

FIG. 7

G.H.P. Del

Forbes Co. Boston

FIG 13

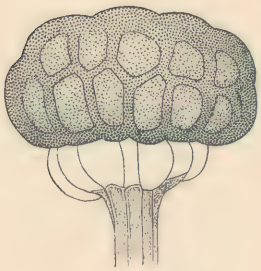

FIG. 10

FIG. 14

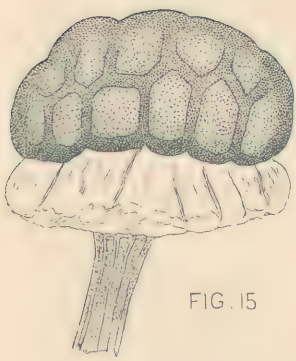

FIG. 15

FIG 12

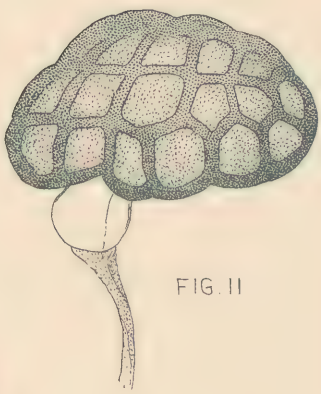

FIG. 11

FIG. 16

FIG. 17

FIG. 19

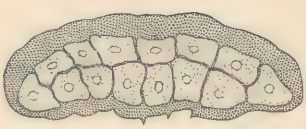

FIG. 20

FIG. 21

FIG. 18

Ravenelia glabra, C. and K.

Fig. 20. A cross-section of a spore-mass treated with potassic hydrate and mounted in balsam.

Ravenelia stictica, Bk. and Br.

Fig. 21. A cross-section of a spore-mass treated with potassic hydrate and mounted in balsam.